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Original Article

EXPERIMENTAL AND CFD INVESTIGATIONS ANALOGY FOR WIND TURBINE EFFICIENCY USING COMMERCIAL SMALL FAN BLADES

S. S. ARULAPPAN

Associate Professor, Department of Mechanical Engineering National Institute of Technology, Tiruchirappalli, Tamil Nadu, India

ABSTRACT

To carry out Comprehensive Experimental, Analytical and Numerical investigations with the Commercial small Fan Blade Physical models to find Efficiency of Energy conversion based on Energy Possessed by the rotating fan blades. Explained with Analytical Reasons and worked with Computer Numerical Fluid Dynamics calculations for both useful energy produced and energy wasted by the running Physical actual commercial fan blades are completed for Ten Individual small Fan Blades. The whole aim is by analyzing the Fan Blade Geometry with their Theoretical and Experimental Performance for a Possible actual Efficiency of Energy utilization by every one of them. A Fan Blade is a Component in a Fan which is used here as a Turbine Blade and which can convert energy from the moving air into another useful form of rotating mechanical kinetic energy. Physical models of the fan blades are held in front of a constant velocity air flow source which a fan and various experiments are conducted using the commercial fan blades having different solidity ratio, blade angle and diameter of rotor and Tip width of the blades. For the Experimental study a Noncontact Tachometer is used to measure the maximum speed of rotation of individual fan blades in r/min when they are actually rotating like wind turbine blades while extracting energy from the Constant Air Flow. The energy possessed by the running rotors and their efficiency of energy conversion are calculated by suitable equations and results are found to be matching with result of CFD Analysis.

KEYWORDS: *Fan Blade, Numerical Fluid Mechanics, Digital Tachometer, CFD Computerized Fluid Dynamics*

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INTRODUCTION

It is a well-known fact that the world population is increasing as a result of which energy demand and actual consumption also increases parallel to the developments in technology. Energy production must meet the needs of this growing human population. Another fact is that the supply of fossil energy resources used so for is alarmingly depleting with increased demand for energy growing up. Considering the negative impacts of fossil fuel energy sources on the environment together with the scarcity of these resources it appears urgent and important to find new energy resources that are clean and renewable. Wind energy is therefore very important as one of these clean energy resources and wind rotors are the most important element in the production of the wind energy.

Potential Power with Wind Energy

Power is available from the kinetic energy of the mass of air moving in wind. The amount of energy that wind carries increases by a factor of three as the speed of wind increases and is proportional to the mass of air that

passes through the plane of rotation of the rotor which is the area swept by the rotor blades. Power produced by the running wind turbine rotor is the product of energy (work) within a given time frame say per second. Density of air is around 1.2 kg / m3 and so power density of wind is much lower than that of water. The power that can be harvested from wind is calculated in terms of the swept area through which the rotor blades sweep. As a result if the diameter of the rotor blades is doubled the power increases by a factor of four. If the wind speed is doubled then power produced increases by a factor of nine In 1920, Albert Betz demonstrated in his theory of the closed stream tube that a wind turbine can only convert a maximum of (16 /27) or 59% of the energy in the wind into useful another form. The best performance is attained when wind turbine rotors slow down the wind by one third of its original speed. A wind turbine model is able to convert up to 49% of energy in the blowing air into rotational kinetic energy thus coming closer to the theoretical limit of 59%.[1].

Analogy Using Fan Rotors with Wind Turbine Energy Conversion

While designing the wind rotor an analogy can be created by testing fan blades. Commercial fan blades are purchased and tested for an optimum blade geometry which can provide a better energy extraction. While analyzing the results of experimental and CFD analysis of commercial fan blades one can get in-depth understanding of design of wind turbine blade geometry which are just similar. [2]

- Mass of fan blade in grams
- Rotational Speed of fan blade (r/min)
- Radius of gyration (k)

For any given rotor mass of rotor will be constant. Velocity of Fan blade depend on input velocity of air or wind flow which will always depend on Nature hence only Radius of Gyration can be designed because it depends largely upon the size of the breath of blade at the rotor tip.

Table 1: Sample of Experimental Test Results Using Commercial Small Fan Blades Efficiency Vs Blade Length

S. No. of Fan Blade	Length of Each Blade (Mm)	Mass of the Rotor (Gm)	Speed of Rotation of Blade (R/Min)	Input Kinetic Energy (J) by Air Flow	Tip Speed Ratio of Fan Blade	Solidity Ratio of Blade Geometry	Efficiency of Energy Conversion by Fan Blades (%)
1	158	12.8	121.2	12.914	2.57	0.29	16.18
2	125	17.1	73.62	8.084	1.9	0.471	12.48
3	191	14.34	151.13	18.87	3.29	0.358	12.18
4	220	12.61	123.71	25.04	2.27	0.271	10.28
5	150	13.1	127.43	11.64	3.9	0.308	16.83
6	190	14.08	145.97	18.67	4.6	0.204	16.82
7	195	18.76	84.93	12.92	2.5	0.40	12.17
8	146	12.85	133.921	11.028	3.13	0.455	32.97
9	190	12.31	156.82	18.67	4.58	0.11	25.11
10	11.1	13.94	54.63	9.8	0.92	0.75	16.06

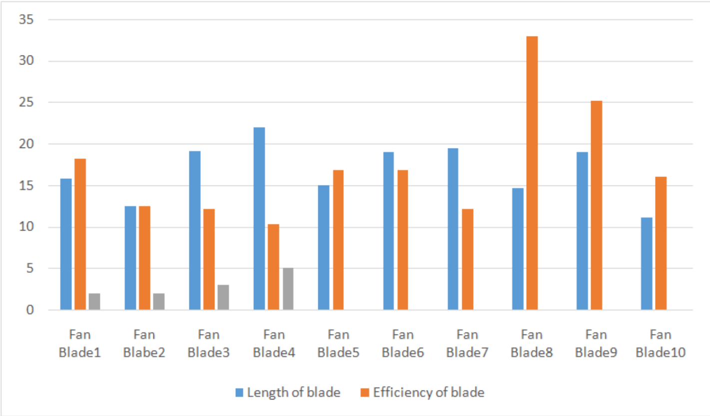

Figure 1: Efficiency Vs Blade Length

Efficiency Vs Mass of Fan Rotor

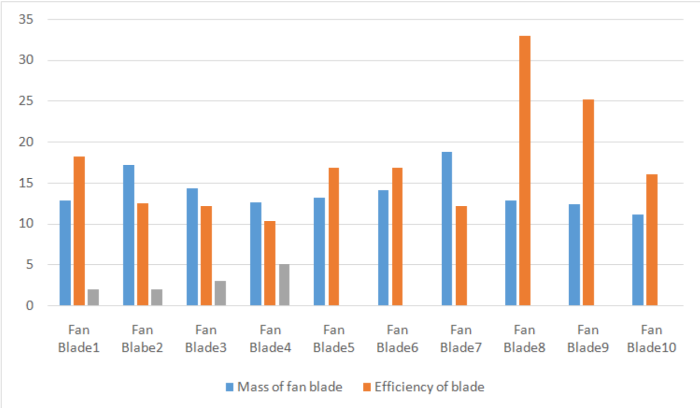

Figure 2: Efficiency Vs Mass of Blade

Efficiency Vs Kinetic Energy

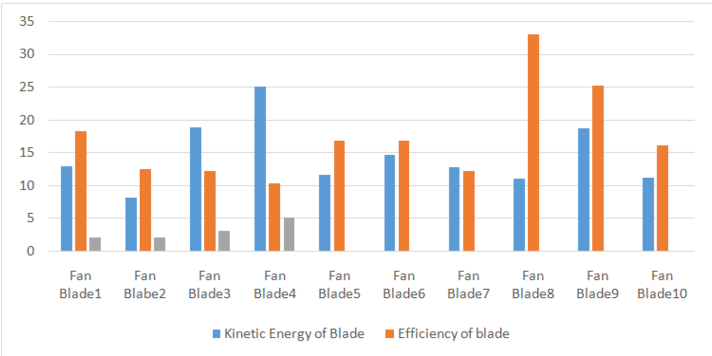

Figure 3: Efficiency Vs Kinetic Energy

Efficiency Vs Tip Speed Ratio

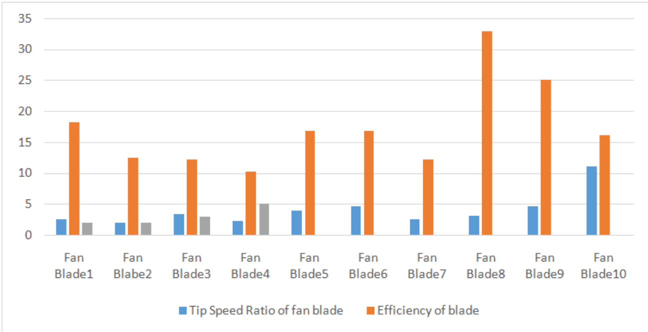

Figure 4: Efficiency Vs Tip Speed Ratio

Efficiency Vs Solidity Ratio

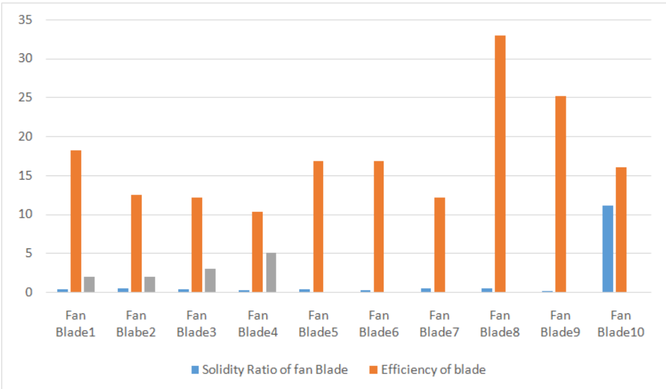

Figure 5: Efficiency Vs Solidity Ratio

ANALYSIS OF EXPERIMENTAL RESULTS USING CFD

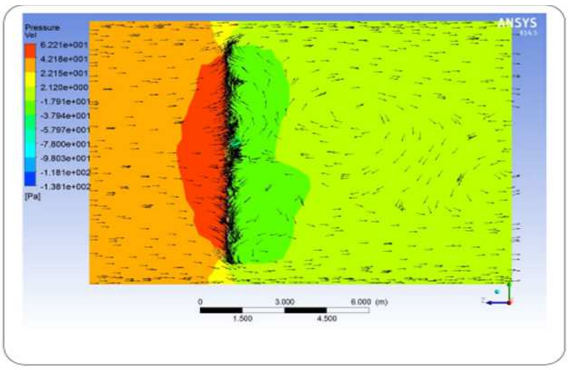

Figure 6: Variation of Air Pressure on Fan Blade

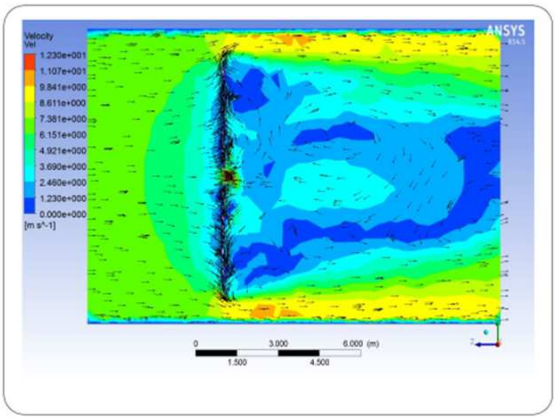

Figure 7: Variation of Velocity of Air Flow on Blade Surface

RESULTS USING CFD

Force on Fan Blade No 7 = 0.0161N

Kinetic Energy of Fan Blade No 7 Using CFD = 0.2571

Experimental Kinetic Energy of Blade No 7 = 0.247

The efficiency of the Fan blade 7 found by experiment is 12.17% and on the basis of CFD it is 14.6%. It means experimental test results is almost matching with CFD analysis.

Figure 8: Small fan blades used

CONCLUSIONS

The efficiency of energy conversion of the fan rotors are found to be strongly depend on Mass of Fan blades, Length of fan blade, Blade angle, Radius of Gyration and Width of the Fan blade Tip. This analogy of energy conversion can help maximizing the energy extraction by the wind turbine rotors and in optimizing the wind turbine rotor geometry.

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